Available online at www.sciencedirect.com
SCIENCE DIRECT
Physica B 329–333 (2003) 1361–1362
PHYSICA B
www.elsevier.com/locate/physb

Superconducting behaviors of copper–germanium alloys

Shih-Ying Hsu*, Jing-Yin Chen

Department of Electrophysics, National Chiao Tung University, Hsinchu 300, Taiwan

Abstract

We have observed superconducting properties in three dimensional Cu_xGe_{100-x} samples with $38 \leqslant x \leqslant 67$. Transition temperature T_c is about 0.4 K. Upper critical magnetic field H_{c2} has been measured in these samples confirming that they are indeed superconductors. Near the zero field T_{co}, H_{c2} depends linearly on temperature. Our results show robust superconducting properties present in CuGe samples with weakly disorder.

Keywords: Superconductivity; Weak disorder; CuGe

1. Introduction

It has been known that as the amount of disorder is increased in a superconductor, the enhanced electron–electron interaction and localization effects have deleterious effects on superconductivity leading a degradation of the transition temperature. On the other hand, it has been reported that the transition temperature of a clean bulk superconductor can be increased by introducing slight disorder in it. Moreover, superconducting properties of AuGe and AuSb were observed [1]. However, most attention is focused on two dimensional superconductor-to-insulator transition. The question why the alloy of two non-superconducting elements does superconduct is still not well understood yet. Here, we present the superconducting properties of 3D CuGe samples in the weakly disordered regime.

2. Experimental details

Our three dimensional amorphous CuGe samples were obtained by thermal evaporation on glass substrates at a rate 0.2 nm/s in vacuum. The alloy sources were fabricated by an arc-melting method. The molar concentration ratios between Cu and Ge in all samples were examined using a SEM energy dispersion spectroscope. Film thicknesses were about 200 nm, measured by surface profile probe. Four terminal AC resistance measurements were performed in a ^{3}He cryostat.

3. Results and discussion

Earlier studies of electrical transport and tunneling density of states in a series of thick CuGe samples reveal that the reduction of Cu concentration relative to Ge enhances electron–electron interactions leading to a weak-to-strong localization transition. The transition occurs around $x \sim 20$ [2]. Fig. 1 shows the evolution of the temperature-dependent resistivities for four Cu_xGe_{100-x} with $38 \leqslant x \leqslant 67$. The resistive transitions are very sharp for all samples indicating the superconductivity of each sample is robust. We associate this drop with the mean-field transition of a superconductor, T_{c0}. For samples with higher concentration of Cu, $x \geqslant 70$, no superconducting behavior above 0.28 K was observed. $T_{c0} = 0.38$ K for $x = 67$ and then, T_{c0} decreases with decreasing x (increasing disorder ρ).

For a type-II superconductor, upper critical field $H_{c2}(T)$ is linear in temperature near the zero field transition temperature T_{c0}. We plot $H_{c2}(T)$ of these four samples in Fig. 2. All data seem to fall on lines except in the regime very close to zero field for the highest disordered sample. The slope gives the information of

*Corresponding author. Fax: 886-3-572-5230.
E-mail address: syhsu@cc.nctu.edu.tw (S.-Y. Hsu).

0921-4526/03/$ - see front matter
doi:10.1016/S0921-4526(02)02230-5

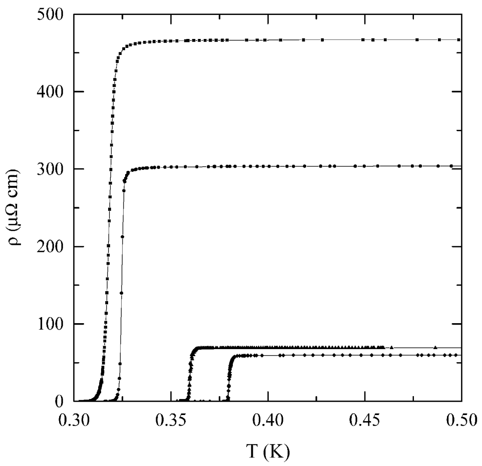

Fig. 1. Resistivity ρ versus temperature T for four Cu_xGe_{100-x} samples with $x = 38(\square)$, $x = 45(\bigcirc)$, $x = 64(\triangle)$, and $x = 67(\diamond)$.

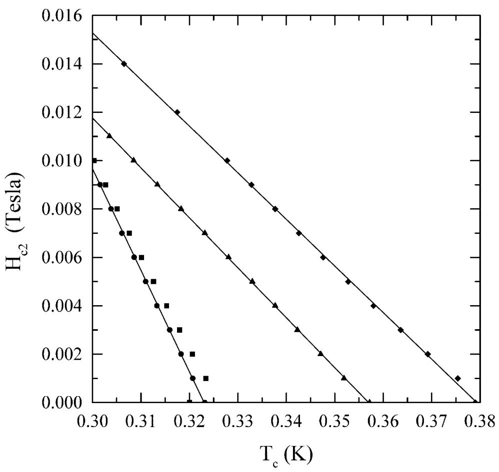

Fig. 2. Critical field H_{c2} versus T_c for four Cu_xGe_{100-x} samples. The symbols are experimental results and three lines are linear fits to data.

diffusion constant,

$$D = \frac{4k_B}{\pi e} \frac{1}{dH_{c2}/dT_c}. \tag{1}$$

The slight deviation from the linear relation near the zero magnetic field for the highest disorder sample may be similar to the magnetic-field-enhanced superconductivity in Au/Ge observed by Seguchi et al. [3].

These samples have resistivities less than 500 μΩ cm and are in the weakly disordered regime. Data shown in Fig. 1 do not show clear pictures of their normal state behaviors in such scales. However, the normal state resistivity of each sample has a $T^{1/2}$ dependence at low temperatures due to the electron–electron interaction effects [4]. It can be described by the theoretical prediction of Altshuler and coworker:

$$\frac{\Delta\rho(T)}{\rho_0} = -\frac{0.915e^2}{4\pi^2\hbar}\left(\frac{4}{3} - \frac{3}{2}F\right)\rho_0\sqrt{\frac{k_B T}{\hbar D}}. \tag{2}$$

where F represents the Coulomb screening effect. F of each sample was obtained by the theoretical fit of its normal state temperature dependent resistivities. Some physical quantities of these four samples are shown in Table 1. As disorder increases, D changes from 6.2 cm^2/s to 1.2 cm^2/s (more diffusive) and F changes from -0.2 to -1.73 (less screening). The result implies that disorder enhances the electron–electron interaction effects as consistent with the observed reduction of T_c in Fig. 1.

Table 1
Some physical quantities of these four Cu_xGe_{100-x} samples

Sample	x	T_{c0} (K)	ρ_0 (μΩ cm)	D (cm^2/s)	F
s1	67	0.380	60	6.20	−0.20
s2	64	0.357	70	5.35	−0.54
s3	45	0.323	300	1.5	−0.82
s4	38	0.320	470	1.1	−1.73

In summary, superconducting properties were observed in weakly disordered CuGe samples. Disorder enhanced electron–electron interaction effects certainly degrade the superconducting properties and therefore, combination of spin–orbital scattering and weak localization may be responsible for the superconducting behaviors. That may explain why T_c is higher in both AuGe and AuSb samples than in our CuGe samples.

Acknowledgements

This work was supported by Taiwan National Science council Grant No. NSC90-2112-M-009-033.

References

[1] T. Furubayashi, et al., Solid State Commun. 55 (1985) 513; P. Haussler, et al., Z. Phys. B 35 (1979) 67; Y. Seguchi, et al., J. Phys. Soc. Japan 62 (1993) 2567.
[2] S.Y. Hsu, et al., Physica B 279 (2000) 1996; S.Y. Hsu, et al., Physica B 284–288 (2000) 1181.
[3] Y. Seguchi, et al., Physica B 194–196 (1994) 2345.
[4] J.-Y. Chen, Ms.D. Thesis, Natl. Chiao Tung U., Taiwan, 2001.